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ORIGINAL INVESTIGATION

Determining the Relationship Between Internal Load Markers and Noncontact Injuries in Young Elite Soccer Players

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Purpose: To examine the association and predictive ability of internal load markers with regard to noncontact injuries in young elite soccer players. ***Methods:*** Twenty-two soccer players (18.6 [0.6] y) who competed in the Spanish U19 League participated in the study. During a full season, noncontact injuries were recorded and, using session rating of perceived exertion, internal weekly load (sum of load of all training sessions and matches for each week) and acute:chronic workload ratio (typically, acute = current week and chronic = rolling 4-wk average) were calculated. A generalized estimating equation analysis was used to examine the association of weekly and acute:chronic load-ratio markers with a noncontact injury in the subsequent week. Load variables were also analyzed for predictive ability with receiver operating characteristic curve and area under the curve. ***Results:*** No association was found for weekly load (odds ratio = 1.00; 90% confidence interval, 0.99–1.00) and acute:chronic load ratio (odds ratio = 0.16; 90% confidence interval, 0.01–1.84) with respect to injury occurrence. In addition, the analyzed load markers showed poor ability to predict injury occurrence (area under the curve < .50). ***Conclusions:*** The results of this study suggest that internal load markers are not associated with noncontact injuries in young soccer players and present poor predictive capacity with regard to the latter.

Keywords: football, training load, sRPE, injury prevention, acute:chronic ratio

Injuries are one of the major problems that soccer players have to face throughout their careers.[1] It has been estimated that during a full season, an U19 soccer team could suffer an injury incidence of 4.40 injuries/1000 h,[2] causing a decrease in sports performance and a high financial loss for the soccer club.[3] In this sense, the average cost of a first-team player in a professional team being injured for 1 month is calculated to be around €500,000.[3] With the aim of reducing soccer players' injuries, multiple preventive strategies (eg, multicomponent protocols and stretching or strength-specific prevention programs) have been applied.[4] However, it seems that these preventive programs are not enough to reduce the injury incidence, mainly due to the high physical demands required during soccer matches.[5] In this sense, quantifying and finely adjusting training and match loads along the week can be useful as a preventive strategy in order to reduce the injury risk in soccer players.[6]

The acute:chronic load ratio (typically, acute = current week and chronic = rolling 4 week average) is considered by the International Olympic Committee to be the most applicable measure of load to identify injury risk in athletes.[7] This ratio that evaluates the load performed by an athlete, with respect to the load he/she has been experiencing in the past weeks,[8] has been associated with injury occurrence in several team sports.[9–11] In general, it is suggested that injury likelihood is low when the acute:chronic load ratio is within a range of 0.8 to 1.3 (protection) and high when the acute:chronic load ratio exceeds 1.5 (risk).[7] In addition to the acute:chronic load ratio, other load markers, such as weekly load (WL), have been used. Although in sports such as rugby there has been a positive relationship between WL and injury incidence,[12] current studies carried out with professional soccer players show contrasting results[13,14]; hence it would be interesting to further study this relationship to clarify this controversy.

When calculating the load and its relation to noncontact injuries, both external load (ie, global positioning system)[15] and internal load (ie, session rating of perceived exertion [sRPE])[13] variables have been used. However, according to the UEFA Elite Club Injury Study,[16] internal load markers have greater relevance as a risk factor than the different markers of external load, hence their recommendations include using the former to establish relationships with noncontact injuries occurrence.[16] This idea makes more sense when working with academy teams, as they usually present special characteristics (eg, "fixed" distribution of the sessions along the microcycle) and do not usually have access to complex devices to quantify the external load. Studies so far in elite soccer have identified potential links of internal load with noncontact injury. Using the sRPE method of quantifying internal load,[17] Fanchini et al[13] found a significant association between acute:chronic load ratio and noncontact injury occurrence (odds ratio [OR] = 2.91; 90% confidence interval [CI], 1.58–5.36) in professional Italian soccer players. In this line, another investigation showed a similar association (OR = 1.49; 90% CI, 1.01–2.23) between acute:chronic internal load and noncontact injuries in Champions League soccer players.[16] However, no research studies have investigated the aforementioned associations in young soccer players belonging to professional soccer academies—a relevant factor, because an injury at this formative stage can be decisive in their prospective careers. Hence replication of previous studies[13,14] using a sample of young elite soccer players is necessary to verify the generalizability of their findings.

Considering the aforementioned evidence and due to the high physiological stress produced by competitive matches,[12] the load

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characteristics in terms of weekly training sessions[14] and the higher injury incidence in professional soccer players,[2] the aim of this study was to determine the association between internal load markers and noncontact injuries and the ability of these measures to predict injury in young elite soccer players. We hypothesized, based on the results obtained with professional soccer players,[13,14] that there would be a significant association between the load markers (ie, WL and acute:chronic load ratio) and noncontact injuries, although those load markers, used in isolation, would have poor predictive ability to accurately identify players that will present an injury.

Methods

Participants

Twenty-two young professional soccer players (age: 18.6 [0.6] y, height: 178 [4] cm, body mass: 72.2 [6.9] kg, and body mass index: 21.9 [1.6] kg/m^2) participated in one full-season (2016/2017) study. Participants belonged to the same team of the Spanish La Liga Club, and they competed in the Spanish First Division Under-19 Championship. Soccer players trained 4 days per week (250–300 min) and competed once a week on the weekends. Those players who were not part of the team in at least 25 weeks were excluded from the subsequent analysis. All the participants were informed of the objectives of the research, participated voluntarily, and had the possibility to withdraw at any time from the investigation without any penalty. All the participants or their parents or tutors (<18 y) signed a written informed consent. The study was conducted according to the Declaration of Helsinki (2013), and the protocol was fully approved by the local research ethics committee before recruitment.

Quantification of Internal Load

According to the UEFA Elite Club Injury Study,[16] an internal measure was chosen to quantify the training workload. In this sense, internal load was assessed using the sRPE method[17] that is validated in soccer,[18] whereby the intensity of the session was multiplied by the duration (range = 50–90 min) for each player for each training session or match. The intensity was determined using the Foster 0–10 scale.[17] Players answered the question, “How hard was your workout?” 30 minutes after every session/match,[18] and the data were collected by the same person (ie, physical trainer). Each player was confidentially interviewed and could not see the values rated by the other participants. All players were previously familiarized with this method at the end of the previous season. WL corresponded to the sum of load for all training sessions and matches for each week. The acute:chronic load ratio was determined by calculating the sum of the current week’s sRPE training load (acute load) and dividing it by the average weekly training load over the previous 4 weeks (chronic load).[19]

Injury-Data Collection

Injuries were registered using a standardized questionnaire and classified according to UEFA criteria for epidemiological studies.[20] An injury was defined as “an injury that occurred during a scheduled training session or match that caused absence from the next training session or match.”[20] As noncontact injury is the most common injury in elite football, and the load will mainly influence this type of injury, only information pertaining to noncontact injuries was collected.[21] For this study, player’s recovery after an injury was considered when the medical staff indicated that the athlete could fully return to training or competition.[14] Individual training exposure was calculated for each player and was considered as the duration in hours corresponding to team-based and individual physical training activities. Injury incidence was calculated as all noncontact injuries per 1000 hours of football activity (training + matches), following previous recommendations.[20]

Statistical Analysis

Association between load and noncontact injuries in the subsequent week was determined using a generalized estimating equation analysis.[22] To analyze longitudinal data with a binary outcome distribution (injury: yes/no), a logit link function was used, and a working correlations matrix was chosen based on quasi-likelihood under the independence model criterion (QIC) (ie, the lower QIC value) with an exchangeable and independent value for WL and acute:chronic internal load ratio, respectively. ORs with 90% CI and magnitude-based inferences were used to interpret the association.[23] The smallest beneficial and harmful effect for a risk ratio was considered as an OR of <0.90 and >1.11, respectively. The effect was considered “unclear” if the chance of the true values being beneficial was >25% with the OR <0.66. If the effect was considered “clear,” thresholds for assigning qualitative terms of beneficial, trivial, and harmful were as follows: <0.5%, most unlikely; 0.5% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possible; 75% to 95%, likely; 95% to 99.5%, very likely; and >99.5%, most likely.[24] WL and acute:chronic load ratio were examined for predictive ability using a receiver operating characteristic (ROC) curve. The ROC curve examines the discriminant ability of a marker to classify players in 2 groups and plots the true positive rate (sensitivity) against the true negative rate (specificity) producing an area under the curve (AUC). An AUC of 1.00 (100%) represents perfect discriminant power, where .50 (50%) would represent no discriminatory power.[25] An AUC > .70 and the lower CI > .50 was classified as a “good” benchmark.[26] All ROC curve results were presented as AUC ± 90% CI. All analyses were performed using Statistical Package for the Social Sciences (version 21; IBM Co, New York, NY) and Excel (Microsoft Excel 2011 for Mac; Microsoft Corp, Redmond, WA).

Results

Internal Workload

During the full season, 141 training sessions (preseason = 21; in-season = 120) and 38 matches (friendly = 8; official = 30) were completed. The average sRPE was 485.86 (198.12) AU in preseason and 571.66 (97.16) AU during in-season (postmatch training = 554.32 (60.17) AU; strength-based training = 628.37 (35.90) AU; conditioning-based training = 621.67 (34.63) AU; prematch training = 517.49 (35.51) AU). Finally, average WL was 2682.07 (733.34) AU in preseason and 2664.21 (432.46) AU during the in-season period.

Injury Incidence

A total of 27 (preseason = 7; in-season = 20) time-loss noncontact injuries were incurred during the season. Noncontact injury incidence for preseason was 8.48/1000 h, while during the in-season period, a noncontact injury incidence of 4.99/1000 h was registered. Injury occurrence, exposure, and injury incidence per match and training are presented in Table 1. Details about type, location, and event[20] are presented in Table 2.

Association and Prediction

Weekly load and injuries showed no association with OR of 1 (90% CI, 0.99–1.00). Acute:chronic load ratio and injuries showed no association with OR 0.16 (90% CI, 0.01 to 1.84). The AUC (90% CI) values derived from the ROC curve of WL and acute:chronic load ratio were .49 (90% CI, .39–.59) and .43 (90% CI, .32–.54), respectively, showing poor predictive ability of noncontact injury.

Discussion

The aim of this study was to determine the association and prediction of internal load markers with noncontact injuries in young elite soccer players. Although previous studies have focused on this topic with professional players, this is the first investigation in which elite young soccer players participated. The results of the study showed that internal load markers were neither associated with injuries nor had predictive capacity to identify soccer players that will incur a noncontact injury.

Internal load monitoring is increasingly popular in high-performance sport to ensure athletes achieve an adequate training stimulus and to minimize the negative consequences of training (ie, injury risk).[6] In this line, some internal load markers have been used to establish possible relationships between training load and injury incidence.[13,14] Traditionally, it has been assumed that, in team sports like rugby or Australian football, there is a close relationship ($r = .82–.86$) between WL and training injury rates,[10,12,27] however, not many investigations have been carried out with elite soccer players.[9] Malone et al[9] showed that those professional players who declared 1-weekly acute load ≥1500 to ≤2120 AU (OR = 1.95; 95% CI, 0.98–3.95) significantly increased their injury risk. In spite of this, it is necessary to take this association with caution, as the fact that all types of injuries (contact and noncontact) were included in the data analysis could have influenced the results obtained. Recent studies carried out with Serie A Italian players[13] and with Champions League players[14] have shown that when only noncontact injuries are taken into account, a significant association ($P < .05$) cannot be established between the reported injuries and the WL. The aforementioned results are in line with those observed in the current study, where despite using a sample with different characteristics (younger elite soccer players), WL and injuries also showed no association. Such results may indicate the low level of association of the WL with noncontact injury occurrence, despite having analyzed it with soccer players of different competitive levels and characteristics. Therefore, further research would be advisable to analyze other internal or external variables that may be associated with the injury occurrence.

Acute:chronic load ratio and injuries showed no association. Previous research across a number of sports like rugby,[11] basketball,[19] or even soccer[9] has found that both low and high load ratios can result in increased injuries, while highlighting the existence of a "sweet spot" load (range = 0.8–1.3) that seems to provide a protective effect in athletes.[7] Fanchini et al[13] analyzed the possible relationship between noncontact injuries and the acute:chronic ratio in first-level soccer players during 3 consecutive seasons, obtaining a significant association (OR = 2.91). Similarly, McCall et al[14] showed a significant association (OR = 1.49) between load ratio and injury occurrence with European top-level players. The results obtained in the current study did not follow the trend of previous soccer studies. This could be explained by the different sample (size and typology) examined in the present study[28] and the number of injuries that occurred. Among different risk factors, age is considered a nonmodifiable risk factor with older athletes being more susceptible to injury.[29] The players examined in the present sample are younger than those presented in the

Table 2 Details of Injuries During the Season

	No. of training injuries	No. of match injuries
Location		
Head/face/neck	0	0
Back/trunk	0	0
Hip/groin	3	3
Thigh	8	5
Knee	4	0
Lower leg	1	0
Ankle	2	0
Foot	0	1
Upper extremity	0	0
Type		
Sprain	5	0
Strain	12	8
Contusion	0	0
Fracture	0	1
Dislocation	0	0
Other	0	0
Overuse	1	0

Table 1 Injury Occurrence, Exposure, and Injury Incidence During the Season per Training and Match

	Preseason	In-season	Total season
No. of noncontact injuries (training)	5	13	18
No. of noncontact injuries (match)	2	7	9
Exposure (training), h	693	3960	4653
Exposure (match), h	132	495	627
No. of injuries (training), per 1000 h	7.22	3.28	3.87
No. of injuries (match), per 1000 h	15.15	14.14	14.35

aforementioned studies (18.6 [0.6] vs ~26 y old), and this may have resulted in a lack of clear association. In addition, and even though a number of 20 to 50 injuries are enough to detect a relationship between risk factors and injury,[29] the small number (ie, 27 injuries) recorded in the present study may have also contributed to the nonassociation between acute:chronic load ratio and injury incidence. In this sense, it would be interesting to conduct studies in young players with a larger sample in order to better understand the acute:chronic ratio and its association with noncontact injury occurrences.

At the time of establishing relationships between the internal load and injuries, the terms association and prediction have mistakenly been used interchangeably, resulting in a significant association between load and injury being considered as "predictive" of injury.[8,30] In the present study, the predictive ability of different load markers was analyzed (ie, WL and acute:chronic load ratio). Poor predictive ability was obtained in both load markers because the ROC curve analysis revealed AUCs < .50, which is lower than AUC > .70, which has to be reported to establish some predictive ability.[25] These results support those obtained in the only studies that have analyzed the predictive ability of load markers in soccer players,[13,14] as, in both previous investigations, poor predictive values were obtained (ie, ≤.60 in all load markers analyzed). In spite of the important differences in the characteristics of the young players in relation to the first-level players (ie, lower number of weekly training sessions or always using the same distribution of sessions along the microcycle), the results obtained confirm the limited predictive ability, in all soccer levels, of the internal load when detecting individuals who will incur noncontact injuries. This aspect could be due to the different effects produced by the same load stimulus on different players. Besides, some indicators such as injury history, years of experience, fitness level, and age are not taken into account by the internal load markers.[19] In addition, understanding the multifactorial nature of injury allows for the recognition of the complex interaction of factors that lead to an injury.[31] Therefore, looking at single risk factor in terms of prediction (or using the word "predict" or "prediction" when examining association) can provide misleading information[30] to practitioners.

This study is not without limitations. The main limitation is the small sample size and, consequently, the small number of injuries to detect associations in a risk factor study; therefore, it would be interesting to carry out this study with several soccer teams and during multiple seasons in order to generalize the findings. The method used to determine the internal load (sRPE), despite having multiple advantages, also has some inconveniencies that should be highlighted, such as the fact that it cannot differentiate between short high-intensity and long low-intensity sessions (a 30-min session with an RPE of 8 and a 120-min session with an RPE session of 2 will yield an sRPE of 240 AU).[7] We thus suggest monitoring both internal (ie, sRPE) and external (ie, global positioning system) loads when implementing an effective load monitoring strategy.[14]

Practical Applications

The lack of association and poor predictive ability of internal load markers found in the present sample suggested that internal load (ie, sRPE) is not a useful method to predict injuries in young players. However, sRPE is a simple and validated method that allows obtaining useful information about training sessions' weekly distribution across individuals with different responses. Considering the lack of association between internal load markers and injuries, further research should consider nonmodifiable risk factors (eg, age, previous injury) and modifiable fitness components (eg, strength) in the screening and monitoring strategies to prevent noncontact injuries in soccer players.

Conclusions

The main results of the current study neither support the association nor the predictive ability of internal load markers using the sRPE method, with regard to noncontact injuries in young elite soccer players. Therefore, internal load monitoring cannot be confidently used in isolation as a tool to predict noncontact injuries in young soccer players, but it can be used to understand how players cope with the demands of the training.

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